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DISCOVERY OF ANOMALOUS STRONG (GIANT) PULSES FROM PSR B0301+19 (J0304+1932) AT 111 MHz

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Abstract. We report the discovery of anomalous strong pulses from PSR B0301+19 (J0304+1932). We analyzed data obtained using Large Phase Array (LPA) radio telescope at 111 MHz in November and December 2012. We detected 884 individual pulses with signal-to-noise ratio exceeding 3 in 34 observational sessions, and nine pulses of them exceeded the peak flux density of the averaged per session (dynamical) profile more than 40 times. The strongest individual pulse observed is 68.7 times as strong as the average profile and has a peak flux density of 295 ± 55 Jy. The flux density distribution of individual pulses was best-fitted with a combination of log-normal and power-law (for strong pulses) distributions. Such a distribution is typical of pulsars with Giant Radio Pulses (GRP). Thus, with a high probability, we can suppose that B0301+19 belongs to the class of pulsars generating GRP.

Introduction

The pulsar B0301+19 (J0304+1932) was observed in the framework of our survey of second period pulsars of the Northern Hemisphere, which has been held since 2012 till now. The main aim of this observational program is the analysis of the behaviour of individual pulsar's pulses for long time intervals and the search for Giant Radio Pulses (GRPs).

PSR B0301+19 is a faint, nearby, isolated radio pulsar, which has a complex mean profile with two components (see Fig. 1, Table 1).

As it was found during preliminary overview of the observational data, the peak flux density of individual pulses demonstrated a high level of instability, sometimes exceeding the mean profile more than 10 times. Usually it is considered as the fulfilment of the "soft" criterion of an anomalous (giant) pulse. This led us to a more careful analysis of these data.

Table 1: Parameters of the pulsar B0301+19 (J0304+1932) [1, 2].

Barycentric pulsar period, P (s)	1.387584446262(3)
Time derivative of barycentric period, $\dot{P}$ (dimensionless)	$1.29523(2) \times 10^{-15}$
Dispersion measure DM ($cm^{-3}pc$)	15.6567(4)
Mean flux density at 400 MHz, S_{400} (mJy)	27(3)
Mean flux density at 111 MHz, S_{111} (mJy, evaluation)	350(40)

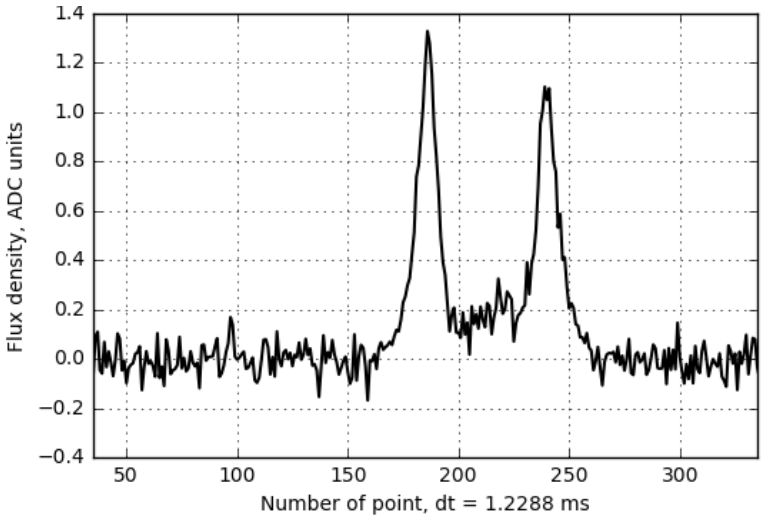

Figure 1: Average profile of PSR B0301+19 obtained by averaging 4964 individual pulses. Time discrete is $dt = 1.2288$ ms.

Observations and processing

Observations were carried out at Pushchino Radio Astronomy Observatory using Large Phased Array (LPA) scanning radio telescope in November and December of 2012. One linear polarization of the 1st antenna diagram was used. The effective area in the zenith direction is estimated as 20000 ± 4000 square meters. The frequency of observations was 111 MHz with a bandwidth of 2.3 MHz. The digital pulsar processor was used in the 460×5 kHz mode with post-detector DM removal. In total 4964 individual pulses in 34 observational sessions were processed. To verify the hypothesis about the presence of GRP in the set of detected strong pulses, we calculated peak flux density distributions in absolute (Jy) units.

Results

For further analysis 884 pulses pulses with peak flux density $S_{\rm peak} > 3\sigma_{\rm noise}$ were selected from the observed data. From this set: 14 pulses with $S_{\rm peak} > 30 \times S_{\rm ave}$, where $S_{\rm ave}$ is dynamical average profile; nine with $S_{\rm peak} > 40 \times S_{\rm ave}$, and two with $S_{\rm peak} > 60 \times S_{\rm ave}$. Peak flux density of the strongest observed individual pulse was 68.7 times as strong as an average profile (see Fig. 2) and was $S_{\rm peak} = 295 \pm 55$ Jy. Peak flux densities were evaluated using the calibration step, we calculated that the ADS unit is about 6.65 K and 2 Jy. The strongest pulses typically have the same durations as the corresponding components of the average profiles.

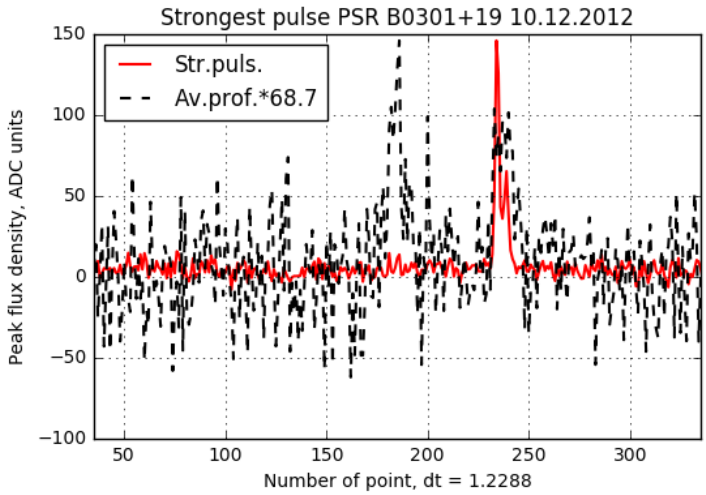

Figure 2: The strongest pulse of PSR B0301+19 observed at 111 MHz in the session of December 10, 2012. An averaged pulse is multiplied by 68.7.

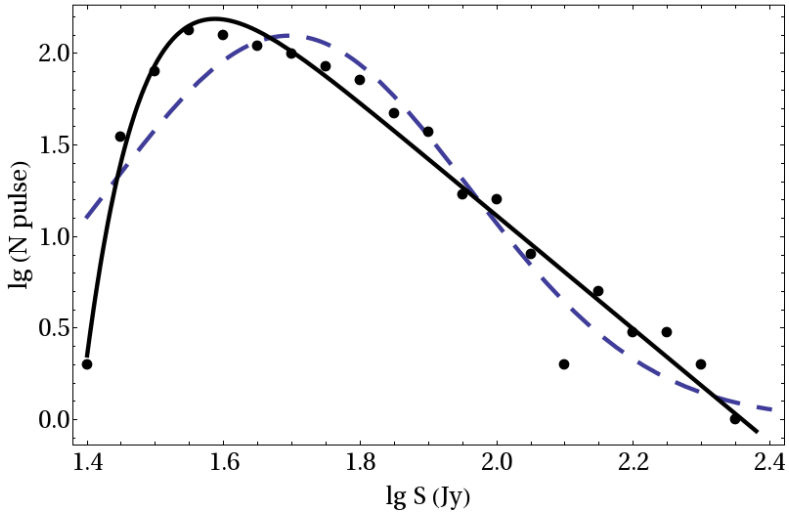

Figure 3: Log-Log plot of the distribution of the peak flux density of individual pulses of PSR B0301+19. Blue dashed line fits the data with the model of log-normal distribution, solid black line fits the model with the sum of log-normal and power-law distributions. The index of the power law distribution is -3.09 ± 0.25. Estimated variance for log-normal fit is $\sigma = 0.273$, and for the fit with the sum of two distributions it is $\sigma = 0.161$.

The distribution of the peak flux density (in analog digital converter units) in the Log-Log scale is shown in Fig. 3. It cannot be fitted satisfactorily with a log-normal distribution only (as regular pulses) and was best-fitted with a sum of log-normal and power-law distributions. The latter distribution is typical of GPRs.

Thus, with a high probability, we can consider B0301+19 as a pulsar generating GRP, because it satisfies several criteria of GRPs: its peak flux density is 30 times stronger than

that of the average pulse; pulses were detected at the phase of the average profile, strong pulses have power-law distributions of the peak flux density. However, the main criteria are not so clearly expressed as for "classical" pulsars with GPs, B0531+21 [3] and the millisecond pulsar B1937+21 [4]. Nevertheless, B0301+19 fits well the sub-class of second period pulsars with low magnetic field on the light cylinder generating GPs at low radio frequencies, such as J0034−0721 [5], J0659+1414 [6], J1115+5030 [7], J1752+2359 [8], J0953+0755 [9, 10], and B1237+25 [11, 12].

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ОТКРЫТИЕ АНОМАЛЬНО МОЩНЫХ (ГИГАНТСКИХ) ИМПУЛЬСОВ ПУЛЬСАРА B0301+19 (J0304+1932) НА ЧАСТОТЕ 111 МГЦ

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Резюме. Мы сообщаем об открытии аномально мощных импульсов от пульсара PSR B0301+19 (J0304+1932). Нами проанализированы данные, полученные на Большой Синфазной Антенне (БСА) на 111 МГц в ноябре и декабре 2012 г. Было зафиксировано 884 индивидуальных импульса с отношением сигнал/шум больше трёх, наблюдённых в 34 сеансах, среди которых девять импульсов превышали пиковую плотность потока среднего за сеанс профиля более чем в 40 раз. Сильнейший наблюдённый индивидуальный импульс в 68.7 раза превышает средний профиль и имеет пиковую плотность потока 295 ± 55 Ян. Распределение пиковой плотности потока индивидуальных импульсов наилучшим образом аппроксимируется комбинацией логнормального и степенного (для сильных импульсов) распределения. Такой тип распределения типичен для пульсаров с гигантскими импульсами (ГИ). Таким образом, с большой вероятностью, мы можем предположить, что B0301+19 относится к классу пульсаров, генерирующих ГИ.